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Paulo R. Martini

Paulo R. Martini

9. Authorship *Raimundo Almeida Filho*

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Responsible author

13. Authorized by

Parada

Nelson de Jesus Parada
Director

14. Abstract/Notes

A multitemporal (multiseasonal) analysis of LANDSAT multispectral images in CCT format permitted the mapping of lithologic facies in the Pedra Branca Granite, using geobotanical associations, which occur in the form of variations in the density of the "cerrado" vegetation, as well as the predominance of certain distinct vegetation species. Dry season images did not show very good results in lithological differentiation due to anomalous illumination conditions related to the low solar elevation and the homogeneity in the vegetation cover, specially the grass that becomes dry during this season. Rainy season images, on the other hand, allowed the separation of the lithological types, a fact that can be attributed to a greater differentiation among the geobotanical associations. As a result of this study, the muscovite-granite facies with greisenization zones within the Serra da Pedra Branca were mapped. This methodology can be sucessfully applied to similar known granite bodies elsewhere in the Tin Province of Goiás.

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MULTITEMPORAL AND GEOBOTANICAL APPROACH IN THE REMOTE DETECTION OF GREISENIZATION AREAS IN THE SERRA DA PEDRA BRANCA GRANITE, GOIÁS STATE, BRAZIL*

R. Almeida Filho

Instituto de Pesquisas Espaciais - INPE
Conselho Nacional de Desenvolvimento Científico e Tecnológico - CNPq
C.P. 515 - São José dos Campos - SP - Brazil

ABSTRACT

A multitemporal (multiseasonal) analysis of LANDSAT multispectral images in CCT format permitted the mapping of lithologic facies in the Pedra Branca Granite, using geobotanical associations, which occur in the form of variations in the density of the "cerrado" vegetation, as well as the predominance of certain distinct vegetation species. Dry season images did not show very good results in lithological differentiation due to anomalous illumination conditions related to the low solar elevation and the homogeneity in the vegetation cover, specially the grass that becomes dry during this season. Rainy season images, on the other hand, allowed the separation of the lithological types, a fact that can be attributed to a greater differentiation among the geobotanical associations. As a result of this study, the muscovite-granite facies with greisenization zones within the Serra da Pedra Branca were mapped. This methodology can be sucessfully applied to similar known granites bodies elsewhere in the Tin Province of Goiás.

1. INTRODUCTION

The goal of this work was to test the applicability of LANDSAT multispectral imagery on discrimination of geobotanical associations observed in zones of cassiterite (Tin-bearing ore) rich metasomatic alteration in the granitic body of Serra da Pedra Branca.

The Serra da Pedra Branca Granite is located approximately 400 km north of Brasília, in Central Brazil (Figure 1). The area is dominated by a semi-humid climate with a rainy season (October to April) characterized by an average precipitation of 1500 mm, and a winter dry season (May to September). The mean annual temperature is around 25°C.

The native vegetation is the Savanna ("Cerrado") characterized by sparse small trees with twisted trunks and branches, some shrubs and a continuous grass mat covering the soil. The grass is very sensitive to the soil water content and becomes dry in prolonged dry spell, or luxuriant soon after the first rain.

2. GENERAL CHARACTERISTICS OF THE PEDRA BRANCA GRANITE

2.1 GEOLOGY

The Serra da Pedra Branca Granite is a dome, 12 km long by 9 km wide; with a relief of around 400 meters. The granite is surrounded by gneisses and migmatites of the undivided basement, probably of archean age, and by metasedimentary and metavolcanic rocks of Middle Proterozoic Arai Group. The contacts are generally by faults. Rb/Sr dating for the granite indicates

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preliminary values around 1600 million years (Hasui et al., 1981).

The geological characteristics of the granite have been described by Padilha & Laguna (1981) in some detail. The Pedra Branca dome is a biotite--granite varying from gray to rose, and from medium to coarse grained texture, but sometimes the granite is locally porphyritic. The granite body suffered intense post-magmatic transformation processes represented by several granitic facies varying from slightly greisenized (muscovite-granite) to typical greisens, strongly controlled by faults and fractures. These lithological types, derived from late differentiations, are light-colored and are cataclastically foliated, which gives them a gneissic appearance. The main region of greisenized muscovite-granite occurrence is located at the western portion of the body, in a basin like depression locally known as "Bacia", with dimensions of 4 km in the north-south direction, and 2 km wide (Figure 2). Typical greisen rocks (quartz-mica) occur at fracture displacement gaps, as lenses that can reach lengths of 100 meters or more. These metasomatic rocks are rich in cassiterite which constitute important deposits of tin.

The cataclastic processes affecting portions of the granite developed extense mylonite belts very similar in appearance to the true greisen zones, that was also affected by these processes, making it very difficult the visual distinction between greisens and mylonites in the field.

2.2 VEGETATION COVER

The occurrence of geobotanical associations adapted to different lithologies is very clear in the Pedra Branca Granite: they appear as variations in the vegetation density or because of the local predominance of some vegetation species best adapted to the soil characteristics. The "cerrado" is found in the more fertile soil derived from biotite-granites, whereas smaller vegetations and grasses are found in the less fertile soil derived from muscovite-granites (Figure 2). In areas where the metasomatic alteration processes were more intense, the soils are still less fertile and much more acid, allowing only the growth of grasses and of a few other very specialized plants such as "Canela-de-Ema" *(Vellozia flavicans)* and the "Barba-de-Bode" grass *(Aristida pallens)*, shown in Figure 3.

3. ANALYSIS OF LANDSAT IMAGES

Computer compatible magnetic tapes of multispectral imagery of the dry and rainy seasons (E-173177 of June 06, 1973 and E-175077 of March 18, 1975, respectivelly) were used in this study. These LANDSAT images covered the area of interest at a time immediately after the discovery of the cassiterite deposits, and were chosen so that later human activities around the deposits, such as the removal of vegetation cover, could be avoided.

These images were analyzed in a Multispectral Image Analyzer/Image-100 (GE, 1975) with a grey scale of 256 levels between zero (black) and 255 (white). The following steps have been used in this work:

A) Image Enlargement - LANDSAT images in computer compatible tapes for the dry and rainy seasons were analized at video scale of 1:75,000.

B) Corrections - the images were corrected for noise effects and atmospheric scattering.

C) Linear Contrast Stretch - Band 5 images of both dry and rainy season were contrast stretched.

D) Ratioing of Non-Correlated Spectral Bands - Ratioing of band 7 by band 5 of rainy season images with a gain of 30.0 and offset of 80.0.

Since most of the information contained in the spectral channels of the visible (Bands 4 and 5) and of the infrared (Bands 6 and 7) are redundant, only bands 5 (0.6 - 0.7 µm) and 7 (0.8 - 1.1 µm) were used.

The products obtained with the use of Contrast Stretch and Band-Ratio Techniques were analysed in conjunction with aerial photographies (at the 1:60.000 scale), topographic charts (at the 1:50,000 scale), light airplane reconnaissance and successive field checking during winter and summer seasons.

3.1 LINEAR CONTRAST STRETCH

The analysis started with Band 5 since the vegetation and bare soil show contrasting spectral behaviour at this interval. The first objective was to characterize areas with varying vegetation cover percentage, representing different geobotanical associations within the Pedra Branca Granite. In this channel the darkest areas (lowest gray levels) would represent regions with more dense vegetation cover, which would correspond to the biotite-granites, whereas the lightest areas (highest grey levels) would represent surface regions with greatest percentage of bare soil and sparse vegetation corresponding to the muscovite-granite zones. Thus, an attempt to increase the contrast between these two areas were made by using a Linear Contrast Stretch of Band 5 of both the dry and rainy season.

Figure 4 shows a contrast stretched enhancement of Band 5 for the dry season (winter) of Serra da Pedra Branca granite. The analysis of the product shows that the tonal variations observed in the enhanced image does not represent, in most of the cases, known regions where different soil-vegetation associations occur within the granite body. Therefore this contrast stretched product contains little clear-cut geobotanical information. Even the broad "Bacia" composed of greisenized muscovite-granite was not well defined by this enhanced product. The observed tonal variations are mainly caused by the particular illumination conditions affected by the relationship between topography and the low angle of sun elevation (30°). During this time of the year the topographic slopes facing the sun appear as light toned region due to the intense frontal solar irradiation. On the other hand, the other slopes facing away from the sun have dark areas because of topographic shadowing.

Besides the non-favorable conditions of illumination, a weak geobotanical differentiation of lithologies in winter images is attributable to the fact that all the grasses are dry at this time. The water deficient grass leaves do not contain the chlorophyll absorption band at 0.65 µm, which consequently makes less contrasting the different vegetation cover densities, otherwise responsible for the tonal variations observed in Band 5.

The image from the rainy season (summer) shows much better the vegetation cover differentiation, adapted to the biotite-granite and the greisenized muscovite-granite. Figure 5 shows the Pedra Branca Granite in a Band 5 image from the rainy season. It can be noticed at the western portion of the body a lighter area corresponding to the muscovite-granite that form the "Bacia" while the remain of the granite body appears in darker shades. This distinction of the "Bacia" is possible at the summer time because all forms of vegetation, including the grasses, are luxuriant in the zones of biotite-granite, at this time of the year, while in areas of the muscovite-granite the presence of water would not change substantially the vegetation cover, due to the acidity in these areas. At these areas the grasses are less developed and their associated "Canela-de-Ema" and "Barba-de-Bode" plants do not change with the season.

The high sun elevation angle observed in summer images (about 46°), is propitious to homogeneous illumination conditions for the whole granitic body, even though there remains a few shadow areas where the relief is accentuated.

3.2 BAND-RATIO TECHNIQUES

Band ratioing between non-correlated LANDSAT images are useful since they can show density variations within the vegetation covering the terrain (Raines et al., 1978). The ratio of band 7 by band 5 ($R_{7,5}$) is directly proportional to the vegetation density of the area: regions with more dense vegetation will appear in light shades in the $R_{7,5}$, whereas those with sparse vegetation will show up in darker tones. Furthermore, ratio images have the ability of condensing spectral information of two bands into a single product, which is less dependent on the illumination within the target of interest.

While the enhancement by contrast stretch of band 5 of the rainy season (Figure 5) was able to delineate with relative assurance only the areas of muscovite-granites of the "Bacia", the product of ratio $R_{7,5}$ of the same time indicated new areas of metasomatic alterations in the Pedra Branca Granite. These areas have been found to be within a grey level interval in the ratio images, that varies from 131 to 181. Figure 6 shows the areas enhanced by a "Level Slicer" (GE, 1975) of the $R_{7,5}$ product and inserted as a theme in Band 7 for better geographic localization within the granite body. The use of the standard Band 7 as a background is necessary since the ratio image cancels identifying morphologic features, by minimizing shadowing effects, which difficult visual identification of geographic reference. In figure 6 the area indicated by the number 1 corresponds to the muscovite-granite that form the "Bacia", partially shown in figure 2. The area marked by number 2 corresponds to new greisenized muscovite-granite geologically identical to the area of "Bacia". In the area marked by number 3, field work indicated the presence of metasomatically altered rocks, but with biotite-granite present at the botton of some valleys. At the high-lying land, however, these areas are covered by quartz pebbles and have a very sparse vegetation cover, very alike the vegetation of areas 1 and 2. The target areas indicated by number 4 correspond to mylonites which are very similar to the greisenized granites that have also been cataclasized, and so they are indistinct in appearance from the mylonites. The target 5 indicates colluvium deposits devoid of vegetation cover. The area shown by number 6 is also a colluvium deposit however in this case is rich in cassiterite originated from the weathering of rocks from the "Bacia".

4. CONCLUSIONS

Band-ratioing of non-correlated channels ($R_{7,5}$) of rainy season (summer) images permits to distinguish areas with different vegetation coverage percentage, which corresponds to geobotanical associations in metasomatic altered zones with cassiterite, in the Pedra Branca Granite. On the other hand, the linear contrast stretch of channel 5, specially of dry season (winter) image is very unsatisfactory for this area.

The results of this study show that LANDSAT-MSS images are very powerful tools and of great potentiality to complement and help the traditional mineral prospecting methods.

The utilization of LANDSAT images must be preceded by judicious analysis, that should consider the type of mineral deposit, its controlling factors, the physiographic characteristics of the region, the role of the ambiental variables, the time of the satellite passage and the use of several computer enhancement techniques.

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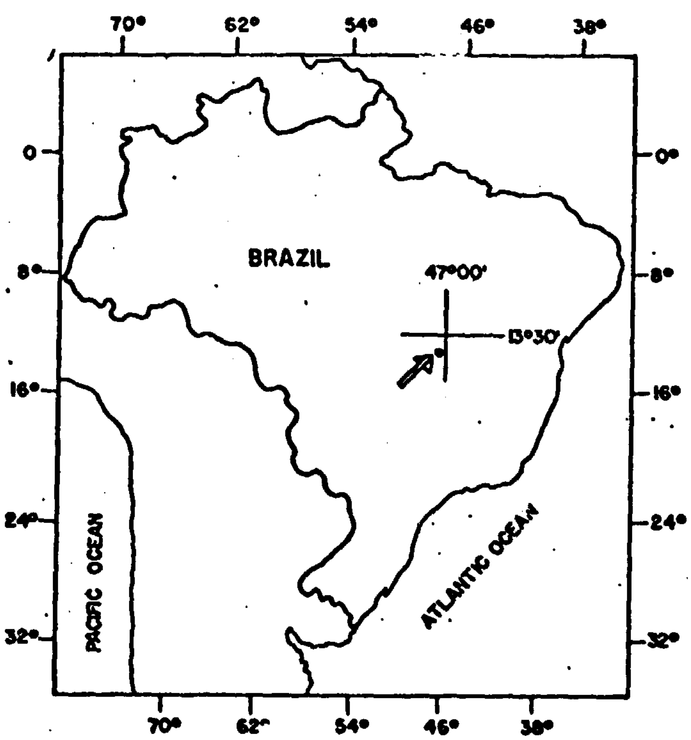

Figure 1. Geographic Localization of the Study Area.

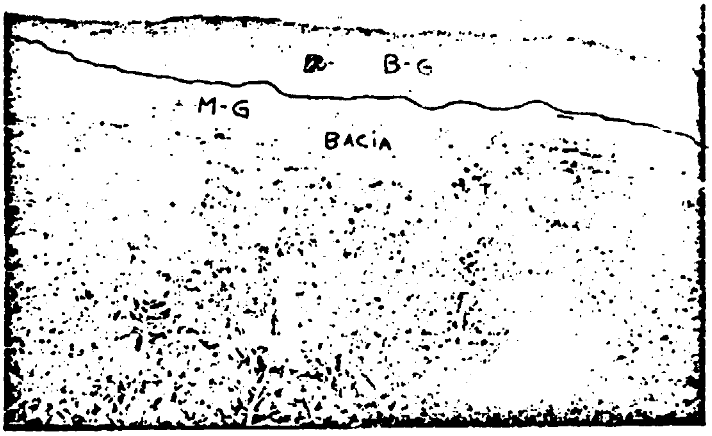

Figure 2. General View of Part of the Top of the Pedra Branca Granite, Showing the Contrasting Vegetation Coverage Between the Biotite-Granite Areas (B-G) and the Muscovite-Granite (M-G) in the "Bacia" Region.

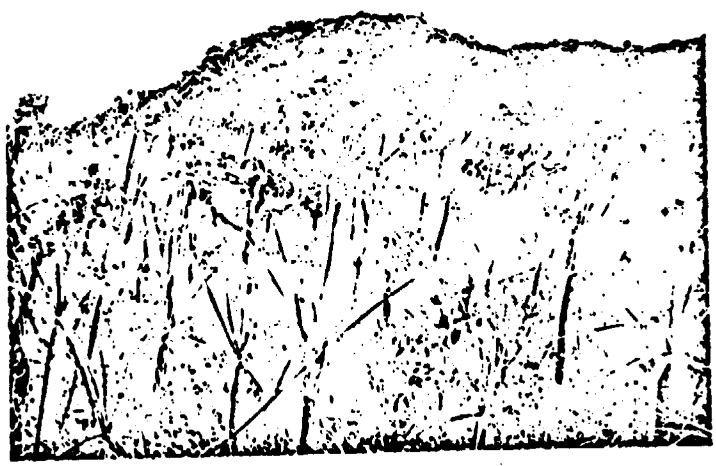

Figure 3. Details of the Vegetation in Areas of Intense Metasomatic Alteration Characterized by the Predominance of the "Canela-de-Ema" and "Barba-de-Bode grass.

Figure 4. Linear Contrast Stretched Band of the Dry Season Image.

Figure 5. Linear Contrast Stretched Band of the Rainy Season.

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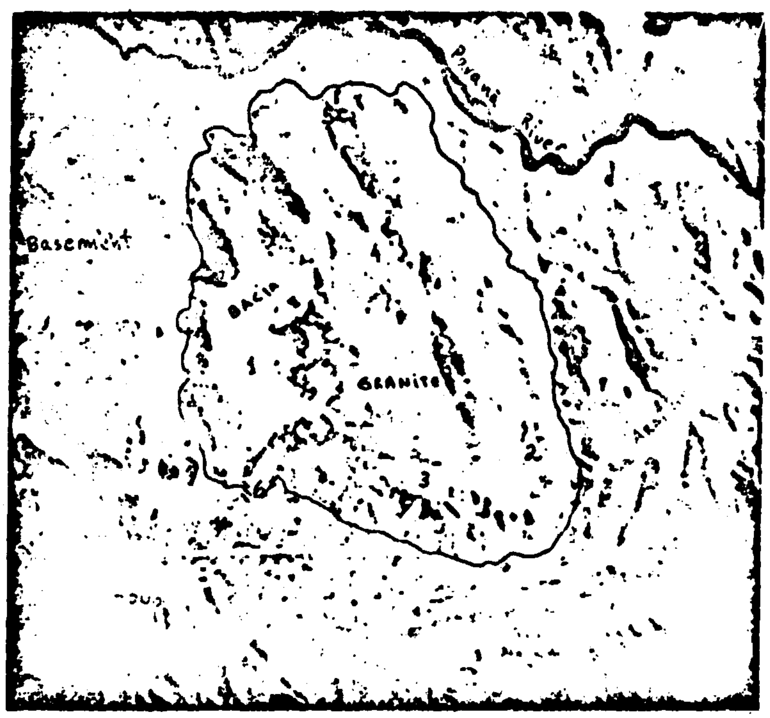

Figure 6. Geobotanical associations indicative of metasomatic and hydrothermal alteration areas within the Serra da Pedra Branca Granite, as shown by band-ratio ($R_{7,5}$). The numbers in the image correspond to target areas described in the text.